of economic geology cannot be separated from that of the recognised principles and methods of inquiry which must be followed by the scientific investigator. On the contrary, the more thoroughly we devote ourselves to the prosecution of geology for its own sake the better able shall we be to appreciate its economic bearings.

In beginning the duties of this Chair, if I enjoy certain advantages over my predecessor, I also at the same time labour under considerable disadvantages. The Class Museum formed by him, and the other appliances and aids to teaching which he laboriously gathered together have been generously handed over to the Chair—and this, I need not say, has greatly smoothed my path. But, on the other hand, he has left behind him a reputation which must bear hard upon me. He has not only sustained but increased the fame of what has been termed the Scottish School of Geology, and I feel that it will task all my energies to emulate the high standard he maintained as a teacher. It is not without diffidence, therefore, that I commence this course; but my hope is that the love of science, which has bitherto carried me over many years of a laborious occupation, may at least succeed in warming and sustaining the enthusiasm of those who come here to study with me what geology has to reveal concerning the past and present.

A METHOD FOR OBSERVING ARTIFICIAL TRANSITS[1]

As many astronomers who intend to observe the coming transit of Venus have neither the time nor means for making the necessary arrangements to practice on artificial transits, the simple method here proposed may be advantageously employed. Instead of observing an artificial sun and planet placed at a distance of several thousand feet from the observer, I would suggest that the real sun be observed, and the planet Venus to be represented by a circular disk, held, in the common focus of the objective and eye-piece, by means of a narrow metallic arm fastened to the eye-piece.

The relative motion of the sun and Venus can then be produced by so adjusting the rate of the driving-clock that the angular motion of the telescope on the hour-axis shall exceed the diurnal motion of the sun by seventeen seconds of time per hour. In this way, as the atmospheric disturbances of the sun's limb are real, a near approach to the phenomena observed during an actual transit will result. If a light-shade glass is employed, the opaque disk will be seen before it comes into apparent contact with the sun. The observer can, however, by an exercise of the will, confine his whole attention to the sun's limb.

By using a heavier shade-glass the disk will not be seen until it is projected against the image of the sun. The angular diameter of Venus at the time of transit being about 65″, the diameter of the opaque disk should be $65 \cdot l \cdot \sin 1'' = 0{\cdot}00031 \cdot l$, l being the focal length of the telescope used. The position angle of the point of contact can be changed at will by simply moving the telescope in declination.

ELECTRIC LIGHTING, THE TRANSMISSION OF FORCE BY ELECTRICITY[2]

Having received the honour of being elected Chairman of the Council of the Society of Arts for the ensuing year, the duty devolves upon me of opening the coming Session with some introductory remarks. Only a few months have elapsed since I was called upon to deliver a presidential address to the British Association at Southampton, and it may be reasonably supposed that I then exhausted my stock of accumulated thought and observation regarding the present development of science, both abstract and applied; that, in fact, I come before you, to use a popular phrase, pretty well pumped dry. And yet so large is the field of modern science and industry, that, notwithstanding the good opportunity given me at Southampton, I could there do only scanty justice to comparatively few of the branches of modern progress, and had to curtail, or entirely omit, reference to others, upon which I should otherwise have wished to dwell. There is this essential difference between the British Association and the Society of Arts, that the former can only take an annual survey of the progress of science, and must then confide to individuals, or to committee, specific inquiries, to be reported upon to the different sections at subsequent meetings; whereas the Society of Arts, with its 3,450 permanent members, its ninety-five associated societies, spread throughout the length and breadth of the country, its permanent building, its well-conducted *Journal*, its almost daily meetings and lectures, extending over six months of the year, possesses exceptionally favourable opportunities of following up questions of industrial progress to the point of their practical accomplishment. In glancing back upon its history during the 128 years of its existence, we discover that the Society of Arts was the first institution to introduce science into the industrial arts; it was through the Society of Arts and its illustrious Past President, the late Prince Consort, that the first Universal Exhibition was proposed, and brought to a successful issue in 1851; and it is due to the same Society, supported on all important occasions by its actual President, the Prince of Wales, that so many important changes in our educational and industrial institutions have been inaugurated, too numerous to be referred to specifically on the present occasion.

Amongst the practical questions that now chiefly occupy public attention are those of Electric Lighting, and of the transmission of force by electricity. These together form a subject which has occupied my attention and that of my brothers for a great number of years, and upon which I may consequently be expected to dwell on the present occasion, considering that at Southampton I could deal only with some purely scientific considerations involved in this important subject. I need hardly remind you that electric lighting, viewed as a physical experiment, has been known to us since the early part of the present century, and that many attempts have, from time to time, been made to promote its application. Two principal difficulties have stood in the way of its practical introduction, viz., the great cost of producing an electric current so long as chemical means had to be resorted to, and the mechanical difficulty of constructing electric lamps capable of sustaining, with steadiness, prolonged effects. The dynamo-machine, which enables us to convert mechanical into electrical force, purely and simply, has very effectually disposed of the former difficulty, inasmuch as a properly conceived and well constructed machine of this character converts more than ninety per cent. of the mechanical force imparted to it into electricity, ninety per cent. again of which may be re-converted into mechanical force at a moderate distance. The margin of loss, therefore, does not exceed twenty per cent., excluding purely mechanical losses, and this is quite capable of being further reduced to some extent by improved modes of construction; but it results from these figures that no great step in advance can be looked for in this direction. The dynamo-machine presents the great advantage of simplicity over steam or other power-transmitting engines; it has but one working part, namely, a shaft which, revolving in a pair of bearings, carries a coil or coils of wire admitting of perfect balancing. Frictional resistance is thus reduced to an absolute minimum, and no allowance has to be made for loss by condensation, or badly fitting pistons, stuffing boxes, or valves, or for the jerking action due to oscillating weights. The materials composing the machine, namely, soft iron and copper wire, undergo no deterioration or change by continuous working, and the depreciation of value is therefore a minimum, except where currents of exceptionally high potential are used, which appear to render the copper wire brittle.

The essential points to be attended to in the conception of the dynamo-machine, are the prevention of induced currrents in the iron, and the placing of the wire in such position as to make the whole of it effective for the production of outward current. These principles, which have been clearly established by the labours of comparative few workers in applied science, admit of being carried out in an almost infinite variety of constructive forms, for each of which may be claimed some real or imaginary merits regarding questions of convenience or cost of production.

For many years after the principles involved in the construction of dynamo-machines had been made known, little general interest was manifested in their favour, and few were the forms of construction offered for public use. The essential features involved in the dynamo-machine, the Siemens armature (1856), the Pacinotti ring (1861), and the self-exciting principle (1867), were published by their authors for the pure scientific interest attached to them, without being made subject matter of letters patent, which circumstance appears to have had the contrary effect of what might have been expected, in that it has retarded the introduction of this class of electrical machine, because no person or firm had a sufficient commercial interest to undertake

[1] By Prof. J. M. Schaeberle, Ann Arbor, Michigan. From the *American Journal of Science*.

[2] Address by Dr. C. W. Siemens, F.R.S., Chairman of the Society of Arts, November 15.

the large expenditure which must necessarily be incurred in reducing a first conception into a practical shape. Great credit is due to Monsieur Gramme for taking the initiative in the practical introduction of dynamo-machines embodying those principles, but when five years ago I ventured to predict for the dynamo-electric current a great practical future, as a means of transmitting power to a distance, those views were still looked upon as more or less chimerical. A few striking examples of what could be practically effected by the dynamo-electric current such as the illumination of the Place de l'Opera, Paris, the occasional exhibition of powerful arc lights, and their adoption for military and lighthouse purposes, but especially the gradual accomplishment of the much desired lamp by incandescence in vacuum, gave rise to a somewhat sudden reversion of public feeling; and you may remember the scare at the Stock Exchange affecting the value of gas shares, which ensued in 1878, when the accomplishment of the sub-division of the electric light by incandescent wire was first announced, somewhat prematurely, through the Atlantic cable.

From this time forward electric lighting has been attracting more and more public attention, until the brilliant displays at the exhibition of Paris, and at the Crystal Palace last year, served to excite public interest, to an extraordinary degree. New companies for the purpose of introducing electric light and power have been announced almost daily, whose claims to public attention as investments were based in some cases upon only very slight modifications of well-known forms of dynamo-machines, of arc regulators, or of incandescent carbon lights, the merits of which rested rather upon anticipations than upon any scientific or practical proof. These arrangements were supposed to be of such superlative merit that gas and other illuminants must soon be matters simply of history, and hence arose great speculative excitement. It should be borne in mind, however, that any great technical advance is necessarily the work of time and serious labour, and that when accomplished, it is generally found that so far from injuring existing industries, it calls additional ones into existence, to supply new demands, and thus gives rise to an increase in the sum total of our resources. It is, therefore, reasonable to expect that side by side with the introduction of the new illuminant, gas lighting will go on improving and extending, although the advantage of electric light for many applications, such as the lighting of public halls and warehouses, of our drawing-rooms and dining-rooms, our passenger steamers, our docks and harbours, are so evident, that its advent may be looked upon as a matter of certainty.

Our Legislature has not been slow in recognising the importance of the new illuminant. In 1879, a Select Committee in the House of Commons instituted a careful inquiry into its nature and probable cost, with a view to legislation, and the conclusions at which they arrived were, I consider, the best that could have been laid down. They advised that applications should be encouraged tentatively by the granting of permissive Bills, and this policy has given rise to the Electric Lighting Bill, 1882, promoted by Mr. Chamberlain, the President of the Board of Trade, regarding which much controversy has arisen. It could, indeed, hardly be expected that any act of legislation upon this subject could give universal satisfaction, because while there are many believers in gas who would gladly oppose any measure likely to favour the progress of the rival illuminant, and others who wish to see it monopolised, either by local authorities, or by large financial corporations, there are others again who would throw the doors open so wide as to enable almost all comers to interfere with the public thoroughfares, for the establishment of conducting wires, without let or hindrance.

The law as now established takes, I consider, a medium course between these diverging opinions, and, if properly interpreted, will protect, I believe, all legitimate interests, without impeding the healthy growth of establishments for the distribution of electric energy for lighting and for the transmission of power. Any firm or lighting company may, by application to the local authorities, obtain leave to place electric conductors below public thoroughfares, subject to such conditions as may be mutually agreed upon, the terms of such license being limited to seven years; or an application may be made to the Board of Trade for a provisional order to the same effect, which, when sanctioned by Parliament, secures a right of occupation for twenty-one years. The license offers the advantage of cheapness, and may be regarded as a purely tentative measure, to enable the firm or company to prove the value of their plant. If this is fairly established, the license would in all probability be affirmed, either by an engagement for its prolongation from time to time, or by a provisional order which would, in that case, be obtained by joint application of the contractor and the local authority. At the time of expiration of the provisional order, a pre-emption of purchase is accorded to the local authority, against which it has been objected with much force by so competent an authority as Sir Frederick Bramwell, that the conditions of purchase laid down are not such as fairly to remunerate the contracting companies for their expenditure and risk, and that the power of purchase would inevitably induce the parochial bodies to become mere trading associations. But while admitting the undesirability of such a consummation, I cannot help thinking that it was necessary to put some term to contracts entered into with speculative bodies at a time when the true value of electric energy, and the best conditions under which it should be applied, are still very imperfectly understood. The supply of electric energy, particularly in its application to transmission of power, is a matter simply of commercial demand and supply, which need not partake of the character of a large monopoly similar to gas and water supply, and which may therefore be safely left in the hands of individuals, or of local associations, subject to a certain control for the protection of public interests. At the termination of the period of the provisional order, the contract may be renewed upon such terms and conditions as may at that time appear just and reasonable to Parliament, under whose authority the Board of Trade will be empowered to effect such renewal.

Complaints appear almost daily in the public papers to the effect that townships refuse their assent to applications by electric light companies for provisional orders; but it may be surmised that many of these applications are of a more or less speculative character, the object being to secure monopolies for eventual use or sale, under which circumstances the authorities are clearly justified in withholding their assent; and no licenses or provisional orders should, indeed, be granted, I consider, unless the applicants can give assurance of being able and willing to carry out the work within a reasonable time. But there are technical questions involved which are not yet sufficiently well understood to admit of immediate operations upon a large scale.

Attention has been very properly called to the great divergence in the opinions expressed by scientific men regarding the area that each lighting district should comprise, the capital required to light such an area, and the amount of electric tension that should be allowed in the conductors. In the case of gas supply, the works are necessarily situated in the outskirts of the town, on account of the nuisance this manufacture occasions to the immediate neighbourhood; and, therefore, gas supply must range over a large area. It would be possible, no doubt, to deal with electricity on a similar basis, to establish electrical mains in the shape of copper rods of great thickness, with branches diverging from it in all directions; but the question to be considered is, whether such an imitative course is desirable on account either of relative expense or of facility of working. My own opinion, based upon considerable practical experience and thought devoted to the subject, is decidedly adverse to such a plan. In my evidence before the Parliamentary Committee, I limited the desirable area of an electric district in densely populated towns to a quarter of a square mile, and estimated the cost of the necessary establishment of engines, dynamo-machines, and conductors, at 100,000*l*. while other witnesses held that areas from one to four square miles could be worked advantageously from one centre, and at a cost not exceeding materially the figure I had given. These discrepancies do not necessarily imply wide differences in the estimated cost of each machine or electric light, inasmuch as such estimates are necessarily based upon various assumptions regarding the number of houses and of public buildings comprised in such a district, and the amount of light to be apportioned to each, but I still maintain my preference for small districts.

By way of illustration, let us take the parish of St. James's, near at hand, a district not more densely populated than other equal areas within the metropolis, although comprising, perhaps, a greater number of public buildings. Its population, according to the preliminary report of the census taken on the 4th April, 1881, was 29,865, it contains 3,018 inhabited houses, and its area is 784,000 square yards, or slightly above a quarter of a square mile.

To light a comfortable house of moderate dimensions in all its parts, to the exclusion of gas, oil, or candles, would require about 100 incandescent lights of from 15 to 18-candle power each, that being, for instance, the number of Swan lights em-

ployed by Sir William Thomson in lighting his house at Glasgow University. Eleven-horse power would be required to excite this number of incandescent lights, and at this rate the parish of St. James's would require 3,018 × 11 = 33,200-horse power to work it. It may be fairly objected, however, that there are many houses in the parish much below the standard here referred to, but on the other hand, there are 600 of them with shops on the ground floor, involving larger requirements. Nor does this estimate provide for the large consumption of electric energy that would take place in lighting the eleven churches, eighteen club-houses, nine concert halls, three theatres, besides numerous hotels, restaurants, and lecture halls. A theatre of moderate dimensions, such as the Savoy Theatre, has been proved by experience to require 1,200 incandescent lights, representing an expenditure of 133 horse power; and about one-half that power would have to be set aside for each of the other public buildings here mentioned, constituting an aggregate of 2,926-horse power; nor does this general estimate comprise street lighting, and to light the six and a half miles of principal streets of the parish with electric light, would require per mile, thirty-five arc lights of 350-candle power each, or a total of 227 lights. This, taken at the rate of 0·8-horse power per light, represents a further requirement of 182-horse power, making a total of 3,108-horse power, for purposes independent of house lighting, being equivalent to one-horse power per inhabited house, and bringing the total requirements up to 109 lights = 12-horse power per house.

I do not, however, agree with those who expect that gas lighting will be entirely superseded, but have, on the contrary, always maintained that the electric light, while possessing great and peculiar advantages for lighting our principal rooms, halls, warehouses, &c., owing to its brilliancy, and more particularly to its non-interference with the healthful condition of the atmosphere, will leave ample room for the development of the former, which is susceptible of great improvement, and is likely to hold its own for the ordinary lighting up of our streets and dwellings.

Assuming, therefore, that the bulk of domestic lighting remains to the gas companies, and that the electric light is introduced into private houses, only, at the rate of, say twelve incandescent lights per house, the parish of St. James's would have to be provided with electric energy sufficient to work (9 + 12) 3,018 = 63,378 lights = 7,042-horse power effective; this is equal to about one-fourth the total lighting power required, taking into account that the total number of lights that have to be provided for a house are not all used at one and the same time. No allowance is made in this estimate for the transmission of power, which, in course of time, will form a very large application of electric energy; but considering that power will be required mostly in the day time, when light is not needed, a material increase in plant will not be necessary for that purpose.

In order to minimise the length and thickness of the electric conductor, it would be important to establish the source of power, as nearly as may be, in the centre of the parish, and the position that suggests itself to my mind is that of Golden-square. If the unoccupied area of this square, representing 2,500 square yards, was excavated to a depth of twenty-five feet, and then arched over so as to re-establish the present ground level, a suitable covered space would be provided for the boilers, engines, and dynamo-machines, without causing obstruction or public annoyance; the only erection above the surface would be the chimney, which, if made monumental in form, might be placed in the centre of the square, and be combined with shafts for ventilating the subterranean chamber, care being taken of course to avoid smoke by insuring perfect combustion of the fuel used. The cost of such a chamber, of engine power, and of dynamo-machines, capable of converting that power into electric energy, I estimate at 140,000*l.* To this expense would have to be added that of providing and laying the conductors, together with the switches, current regulators, and arrangements for testing the insulation of the wire.

The cost and dimensions of the conductors would depend upon their length, and the electromotive force to be allowed. The latter would no doubt be limited, by the authorities, to the point at which contact of the two conductors with the human frame would not produce injurious effects, or say to 200 volts, except for street lighting, for which purpose a higher tension is admissible. In considering the proper size of conductor to be used in any given installation, two principal factors have to be taken into account; first, the charge for interest and depreciation on the original cost of a unit length of the conductor; and, secondly, the cost of the electrical energy lost through the resistance of a unit of length. The sum of these two, which may be regarded as the cost of conveyance of electricity, is clearly least, as Sir William Thomson pointed out some time ago, when the two components are equal. This, then, is the principle on which the size of a conductor should be determined.

From the experience of large installations, I consider that electricity can, roughly speaking, be produced in London at a cost of about one shilling per 10,000 Ampère-Volts or Watts (746 Watts being equal to one horse-power) for an hour. Hence, assuming that each set of four incandescent lamps in series (such as Swan's, but for which may be substituted a smaller number of higher resistance and higher luminosity) requires 200 volts electromotive force, and 60 Watts for their efficient working, the total current required for 64,000 such lights is 19,200 ampères, and the cost of the electric energy lost by this current in passing through ·01-100th of an ohm resistance, is 16*l.* per hour.

The resistance of a copper bar one quarter of a mile in length, and one square inch in section, is very nearly 1-100th of an ohm, and the weight is about $2\frac{1}{3}$ tons. Assuming, then, the price of insulated copper conductor at 90*l.* per ton, and the rate of interest and depreciation at $7\frac{1}{2}$ per cent., the charge per hour of the above conductor, when used eight hours per day, is $1\frac{1}{3}$*d.* Hence, following the principle I have stated above, the proper size of conductor to use for an installation of the magnitude I have supposed, would be one of 48·29 inches section, or a round rod eight inches diameter.

If the mean distance of the lamps from the station be assumed as 350 yards, the weight of copper used in the complete system of conductors would be nearly 168 tons, and its cost 15,120*l.* To this must be added the cost of iron pipes, for carrying the conductors underground, and of testing boxes, and labour in placing them. Four pipes of 10 inch diameter each, would have to proceed in different directions from the central station, each containing sixteen separate conductors of one inch diameter, and separately insulated, each of them supplying a sub-district of 1,000 lights. The total cost of establishing these conductors may be taken at 37,000*l.*, which brings up the total expenditure for central station and leads to 177,000*l.* I assume the conductors to be placed underground, as I consider it quite inadmissible, both as regards permanency and public safety and convenience, to place them above ground, within the precincts of towns. With this expenditure, the parish of St. James's would be supplied with the electric light to the extent of about 25 per cent, of the total illuminating power required. To provide a larger percentage of electric energy would increase the cost of establishment proportionately; and that of conductors, nearly in the square ratio of the increase of the district, unless the loss of energy by resistance is allowed to augment instead.

It may surprise uninitiated persons to be told that to supply a single parish with electric energy necessitates copper conductors of a collective area equal to a rod of eight inches in diameter; and how, it may be asked, will it be possible under such conditions to transmit the energy of waterfalls to distances of twenty or thirty miles, as has been suggested? It must indeed be admitted that the transmission of electric energy of such potential (200 volts) as is admissible in private dwellings would involve conductors of impracticable dimensions, and in order to transmit electrical energy to such distances, it is necessary to resort in the first place to an electric current of high tension. By increasing the tension from 200 to 1,200 volts the conductors may be reduced to one-sixth their area, and if we are content to lose a larger proportion of the energy obtained cheaply from a waterfall, we may effect a still greater reduction. A current of such high potential could not be introduced into houses for lighting purposes, but it could be passed through the coils of a secondary dynamo-machine, to give motion to another primary machine, producing currents of low potential to be distributed for general consumption. Or secondary batteries may be used to effect the conversion of currents of high into those of low potential, whichever means may be found the cheaper in first cost, in maintenance, and most economical of energy. It may be advisable to have several such relays of energy for great distances, the result of which would be a reduction of the size and cost of conductor at the expense of final effect, and the policy of the electrical engineer will, in such cases, have to be governed by the relative cost of the conductor, and of the power at its original source. If

secondary batteries should become more permanent in their action than they are at the present time, they may be largely resorted to by consumers, to receive a charge of electrical energy during the day time, or the small hours of the night, when the central engine would otherwise be unemployed, and the advantage of resorting to these means will depend upon the relative first cost, and cost of working the secondary battery and the engine respectively. These questions are, however, outside the range of our present consideration.

The large aggregate of dwellings comprising the metropolis of London covers about seventy square miles, thirty of which may be taken to consist of parks, squares, and sparsely inhabited areas, which are not to be considered for our present purpose. The remaining forty square miles could be divided into say 140 districts, slightly exceeding a quarter of a square mile on the average, but containing each fully 3,000 houses, and a population similar to that of St. James's.

Assuming twenty of these districts to rank with the parish of St. James's (after deducting the 600 shops which I did not include in my estimate) as central districts, sixty to be residential districts, and sixty to be comparatively poor neighbourhoods, and estimating the illuminating power required for these three classes in the proportion of 1 to $\frac{2}{3}$ to $\frac{1}{3}$, we should find that the total capital expenditure for supplying the metropolis with electric energy to the extent of 25 per cent. of the total lighting requirements would be—

$$\begin{aligned} 20 \times \phantom{\tfrac{2}{3} \times{}} 177{,}000 &= 3{,}540{,}000l. \\ 60 \times \tfrac{2}{3} \times 177{,}000 &= 7{,}080{,}000l. \\ 60 \times \tfrac{1}{3} \times 177{,}000 &= 3{,}540{,}000l. \\ \hline & 14{,}160{,}000l. \end{aligned}$$

or say 14,000,000*l.*, without including lamps and internal fittings, and making an average capital expenditure of 100,000*l.* per district.

To extend the same system over the towns of Great Britain, and Ireland would absorb a capital exceeding certainly 64,000,000*l.*, to which must be added 16,000,000*l.* for lamps and internal fittings, making a total capital expenditure of 80,000,000*l.* Some of us may live to see this capital realised, but to find such an amount of capital, and, what is more important, to find the manufacturing appliances to produce work representing this value of machinery and wire, must necessarily be the result of many years of technical development. If, therefore, we see that electric companies apply for provisional orders to supply electric energy, not only for every town throughout the country, but also for the colonies, and for foreign parts, we are forced to the conclusion that their ambition is somewhat in excess of their power of performance; and that no provisional order should be granted except conditionally on the work being executed within a reasonable time, as without such a provision the powers granted may have the effect of retarding instead of advancing electric lighting, and of providing an undue encouragement to purely speculative operations.

The extension of a district beyond the quarter of a square mile limit, would necessitate an establishment of unwieldy dimensions, and the total cost of electric conductors per unit area would be materially increased; but independently of the consideration of cost, great public inconvenience would arise in consequence of the number and dimensions of the electric conductors, which could no longer be accommodated in narrow channels placed below the kerb stones, but would necessitate the construction of costly subways—veritable *cava electrica.*

The amount of the working charges of an establishment comprising the parish of St. James's would depend on the number of working hours in the day, and on the price of fuel per ton. Assuming the 64,000 lights to incandesce for six hours a day, the price of coal to be 20*s.* a ton, and the consumption 2lbs. per effective horse power per hour, the annual charge under this head, taking eight hours' firing, would amount to about 18,300*l.*, to which would have to be added for wages, repairs, and sundries, about 6,000*l.*, for interest with depreciation at seven-and-a-half per cent., 13,300*l.*, and for general management say, 3,400*l.*, making a total annual charge of 41,000*l.*, or at the rate of 12*s.* 9½*d.* per incandescent lamp per annum. To this has to be added the cost of renewal of lamps, which may be taken at 5*s.* per lamp of sixteen candles, lasting 1,200 hours, or to 9*s.* per annum, making a total of 21*s.* 9½d. per lamp for a year.

In comparing these results with the cost of gas-lighting, we shall find that it takes 5 cubic feet of gas, in a good argand burner, to produce the same luminous effect as one incandescent light of 16-candle power. In lighting such a burner every day for six hours on the average, we obtain an annual gas consumption of 10,950 cubic feet, the value of which, taken at the rate of 2*s.* 8*d.* per thousand, represents an annual charge of 29*s.*, showing that electric light by incandescence, when carried out on a large scale, is decidedly cheaper than gas-lighting at present prices, and with the ordinary gas-burners.

On the other hand, the cost of establishing gas-works and mains of a capacity equal to 64,000 argand burners would involve an expenditure not exceeding 80,000*l.* as compared with 177,000*l.* in the case of electricity; and it is thus shown that although it is more costly to establish a given supply of illuminating power by electricity than gas, the former has the advantage as regards current cost of production.

It would not be safe, however, for the advocates of electric lighting to rely upon these figures as representing a permanent state of things. In calculating the cost of electric light, I have only allowed for depreciation and 5 per cent. interest upon capital expenditure, whereas gas companies are in the habit of dividing large dividends, and can afford to supply gas at a cheaper rate, by taking advantage of recent improvements in manufacturing operations, and of the ever-increasing value of their by-products, including tar, coke, and ammoniacal liquor. Burners have, moreover, been recently devised by which the luminous effect for a given expenditure of gas can be nearly doubled by purely mechanical arrangements, and the brilliancy of the light can be greatly improved.

On the other hand, electric lighting also may certainly be cheapened by resorting, to a greater extent than has been assumed, to arc lighting, which though less agreeable than the incandescent light for domestic purposes, can be produced at less than half the cost, and deserves on that account the preference for street lighting, and for large halls, in combination with incandescent lights. Lamps by incandescence may be produced hereafter at a lower cost, and of a more enduring character.

Considering the increasing public demand for improved illumination, it is not unreasonable to expect that the introduction of the electric light to the full extent here contemplated, would go hand in hand with an increasing consumption of gas for illuminating and for heating purposes, and the neck-to-neck competition between the representatives of the two systems of illumination, which is likely to ensue, cannot fail to improve the quality, and to cheapen the supply of both, a competition which the consuming public can afford to watch with complacent self-satisfaction. Electricity must win the day, as the light of luxury; but gas will, at the same time, find an ever-increasing application for the more humble purposes of diffusing light.

In my address to the British Association I dwelt upon the capabilities and prospects of gas, both as an illuminant and as a heating agent, and I do not think that I was over-sanguine in predicting for this combustible a future exceeding all present anticipations.

I also called attention to the advantages of gas as a heating agent, showing that if supplied specially for the purpose, it would become not only the most convenient, but by far the cheapest form of fuel that can be supplied to our towns. Such a general supply of heating separately from illuminating gas, by collecting the two gases into separate holders during the process of distillation, would have the beneficial effects—

1. Of giving to lighting gas a higher illuminating power.
2. Of relieving our towns of their most objectionable traffic—that in coal and ashes.
3. Of effecting the perfect cure of that bugbear of our winter existence—the smoke nuisance.
4. Of largely increasing the production of those valuable by-products, tar, coke, and ammonia, the annual value of which already exceeds by nearly 3,000,000*l.* that of the coal consumed in the gas-works.

The late exhibitions have been beneficial in arousing public interest in favour of smoke abatement, and it is satisfactory to find that many persons, without being compelled to do so, are now introducing perfectly smokeless arrangements for their domestic and kitchen fires.

The Society of Arts, which for more than 100 years has given its attention to important questions regarding public health, comfort, and instruction, would, in my opinion be the proper body to examine thoroughly into the question of the supply and economical application of gas and electricity for the purposes of lighting, of power production, and of heating. They would

thus pave the way to such legislative reform as may be necessary to facilitate the introduction of a national system.

If I can be instrumental in engaging the interest of the Society in these important questions, especially that of smoke prevention, I shall vacate this chair next year with the pleasing consciousness that my term of office has not been devoid of a practical result.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—In the Higher Local Examination, in which the majority of the candidates are women, there was a notable falling off this year in the number of candidates in the Natural Science group of subjects. In 1880 there were 99, and 26 failed; in 1881 there were 89, and 17 failed; in 1882, only 39, and 9 failed. The total number of candidates increased from 882 in 1881 to 961 in 1882. The examiners' reports do not indicate any special falling off in the attainments shown by the candidates. In the elementary paper (including Physics, a d Biology) the results were not particularly satisfactory. Confusion in the use of terms was common, and the inability to use chemical formulæ was very marked in some cases. In Physiology mistakes were made with regard to subjects of great practical interest, and many of them might have been avoided by reference to every-day experience. In Chemistry the theory was better understood than practical laboratory details.

A supplementary local examination was held in September, for the benefit of candidates seeking exemption from the Previous Examination, and of others desiring to become medical students, &c. Nineteen intending medical students entered, none of whom satisfied the requirements of the General Medical Council.

The Fellows elected at St. John's College last week included Prof. W. J. Sollas, 1st class in the Natural Science Tripos, 1873, Professor of Geology in University College, Bristol, and author of many valuable geological and palæontological memoirs; Mr. J. S. Yeo, Second Wrangler and Second Smith's Prizeman, 1882.

Dr. Hans Gadow will conduct an advanced class in the Morphology of the Vertebrata at the New Museums during the remainder of the present term.

The Members appointed by the Senate on the General Board of Studies, on which much important work will henceforth devolve, are Messrs. Bradshaw (University Librarian), J. Peile, Prof. Cayley, Aldis Wright, Dr. Parkinson, Coutts Trotter, Dr. Phear (Master of Emmanuel College), and Prof. Stuart.

The special Boards of Studies relating to Natural Sciences have selected the following representatives on the General Board of Studies:—Medicine, Prof. Paget; Mathematics, Dr. Ferrers; Physics and Chemistry, Prof. Liveing; Biology and Geology; Music, Mr. Sedley Taylor.

Prof. Stuart has issued his address as the liberal candidate for the University, in succession to the Right Hon. Sir H. Walpole, who proposes to resign.

SCIENTIFIC SERIALS

The American Journal of Science, October.—Notes on physiological optics, No. 5.—Vision by the light of the electric spark, by W. L. Stevens.—Crystals of monazite from Alexander county, North Carolina, by E. S. Dana.—Occurrence and composition of some American varieties of monazite, by S. L. Penfield.—Irregularities in the amplitude of oscillation of pendulums, by C. S. Peirce.—The Deerfield dyke and its minerals, by B. K. Emerson.—Occurrence of *Siphonotreta scotica* in the Utica formation near Ottawa, Ontario, by J. F. Whiteaves.—A recent species of *Heteropora*, from the Strait of Juan de Fuca, by the same.—Notes on interesting minerals occurring near Pike's Peak, Colorado, by W. Cross and W. F. Hillebrand.

Journal of the Asiatic Society of Bengal, vol. 4, part 2, No. 1 (August 31, 1882), contains: On a collection of Japanese Clausiliæ made by Surgeon R. Hungerford in 1881, by Dr. O. F. von Möllendorff (plate 1); out of 21 species, 10 are described as new. Also, by the same author, on *Clausilia nevilliana*, a new species from the Nicobars, and descriptions of three new Asiatic Clausiliæ.—Second list of Diurnal Lepidoptera from the Nicobars, by J. Wood-Mason and L. de Nicéville (plate 3).—On some new or little-known Mantodea, by J. Wood-Mason

Bulletin de l'Academie Royale des Sciences de Belgique, No. 8.—On the new note of M. Dupont concerning his re-vindication of priority of M. Dewalque.—On the means proposed for calming the waves of the sea, by M. Van der Mensbrugghe.—On the dilatation of some isomorphous salts, by M. Spring.—Notes of comparative physiology, by M. Fredericq.—On some brominated derivatives of camphor, by M. de la Royère.—On the central bone of the carpus in mammalia, by M. Lebourcq.—Action of chlorine on sulphonic combinations, and on organic oxysulphides, by MM. Spring and Wissinger.

Verhandlungen der Naturforschenden Gesellschaft in Basel, Theil 7, Heft 1, 1882, contains: Studies on the history of the deer family, No. 1.—The skull structure, by L. Rütimeyer.—Studies on *Talpa europæa*, by Dr. J. Kober. The literature is given in detail, followed by notes on the mole's place in the order, its local names and habits, and on its anatomy and development (plates 1 and 2, chiefly relating to dentition and embryos).—First supplement to the Catalogue of the Collection of Reptiles in the Basle Museum, by F. Müller. Notes are appended to some of the rarer species, and a new genus and species (*Tropidocephalus azureus*) are indicated for a form allied to *Leiodera chilensis*, Gray, taken in Uruguay; it is figured on plate 3. The register of the collection to December, 1881 indicates 933 species.—On the hail-storm of June 29, 1879, by E. Haigenbach-Bischoff and others.—On the explosive powers of ice and on the Gletscherkorn, by E. H. Bischoff.—Meteorological Report for 1881, with reports by L. Rütimeyer on the comparative anatomy collections, and by F. Burckhardt and R. Holtz, on the map collection of the Society.

SOCIETIES AND ACADEMIES

LONDON

Mathematical Society, November 9.—Mr. S. Roberts, F.R.S., president, in the chair.—After the reading of the Treasurer's and Secretaries' reports, the Chairman briefly touched upon the loss the Society had sustained during the recess, by the death of Prof. W. Stanley Jevons, F.R.S.—After the ballot for the Council of the ensuing session had been taken, Prof. Henrici, F.R.S., the newly elected president, took the chair, and called upon Mr. Roberts to read his address, which was entitled, "Remarks on Mathematical Terminology and the Philosophical Bearing of Recent Mathematical Speculations concerning the Realities of Space."—Mr. W. M. Hicks was admitted into the Society.—The following communications were made:—On in- and circumscribed polyhedra, Prof. Forsyth.—Note on quartic curves in space, Dr. Spottiswoode, P.R.S.—Note on the derivation of elliptic function formulæ from confocal conics, Mr. J. Griffiths.—On the explicit integration of certain differential re solvents, Sir J. Cockle, F.R.S.—On compound determinants, Mr. R. F. Scott.—On unicursal twisted quartics, Mr. R. A. Roberts.

Geological Society, November 1.—J. W. Hulke, F.R.S., president, in the chair.—Prof. Louis Lartet, of Toulouse, was elected a Foreign Correspondent of the Society.—The following communications were read:—The Hornblendic and other schists of the Lizard District, with some additional notes on the Serpentine, by Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S. The author described the metamorphic series, chiefly characterised by hornblendic schist, which occupies the southern portion of the Lizard and an extensive tract to the north of the serpentine region, besides some more limited areas. He found that this series was separable into a lower or micaceous group—schists with various green minerals (often a variety of hornblende), or with brownish mica; a middle or hornblendic group, characterised by black hornblende; and an upper or granulitic group, characterised by bands of quartz-felspar rock, often resembling in appearance a vein-granite. These are all highly metamorphosed; yet the second and third occasionally retain to a remarkable extent indications of the minuter bedding structures, such as alternating lamination and current bedding of various kinds. They form, in the author's opinion, one continuous series, of which the uppermost is the thinnest. The general strike of the series, though there are many variations, is either north-west or west-north-west. The junctions of the Palæozoic with the metamorphic series at Polurrian and at Porthalla were described. These are undoubtedly faulted: and the two rocks differ greatly, the former being a slate like any ordinary Palæozoic rock, the other a highly metamorphosed schist. Moreover,